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THE ANASTASIA FORMATION IN PALM BEACH AND MARTIN COUNTIES, FLORIDA

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ABSTRACT

Two facies are recognized in the Pleistocene Anastasia Formation in Palm Beach and Martin Counties: a coquina facies and a shellrock facies. The coquina facies is confined to the topographic high of the Atlantic Coastal Ridge and is believed to represent a former offshore bar complex. The shellrock facies is found in the lower lying areas to the west and may have been a shallow bay behind the offshore bar. In the offshore bar complex two environments are believed to have existed side-by-side: (1) a high-energy environment of active waves and currents where bedded coquina accumulated, and (2) a low-energy environment of reduced sedimentation where the coquina became extensively burrowed. The shellrock is also believed to have been deposited in a low-energy environment. Here reduced wave and current activity permitted the presence of a remarkably large and varied molluscan fauna.

INTRODUCTION

The Pleistocene Anastasia Formation is exposed at numerous places along the coast of Palm Beach and Martin Counties, and is found inland beneath the surface veneer of sands where it is mined as shellrock (Fig. 1) Two facies are recognized in the Anastasia Formation in Palm Beach and Martin Counties: a coquina facies and a shellrock facies. Each facies has distinctive lithologies, fossil contents, and sedimentary structures that provide clues to the type of environment in which the facies was deposited.

FACIES OF THE ANASTASIA FORMATION

The name Anastasia Formation is used for the coquina rock found along the east coast of Florida in a narrow belt from Anastasia Island on the north (the type locality) to Boca Raton on the south, a distance of more than two hundred and fifty miles (Vernon and Puri, 1964). South of Boca Raton the coquina grades into the Miami Limestone, which is believed to be 130,000 years old (Halley and Evans, 1983). The Anastasia Formation is the youngest marine Pleistocene deposit found in the coastal portions of Palm Beach and Martin Counties. Parker, et al., (1955) state that its thickness may exceed 30 meters (100) feet) in some places. It is overlain by unconsolidated quartz, sand, mud or peat of Holocene age. Two facies are recognized in the Anastasia Formation in Palm Beach and Martin Counties: a coquina facies and a shellrock facies. The coquina facies is confined to the topographic high of the Atlantic Coastal Ridge and the shellrock facies is found farther west.

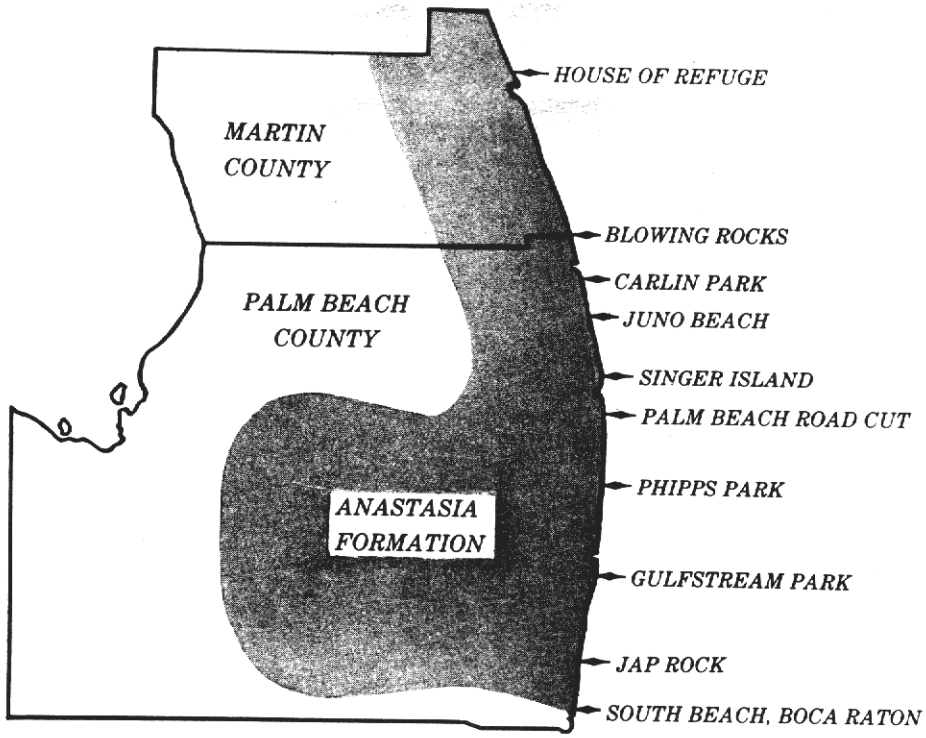

Figure 1. Major outcrops of the Anastasia Formation in Palm Beach and Martin Counties. Geology after Vernon and Puri (1964).

Figure 2. Bedded coquina with Type # 2 burrows, House of Refuge.

The Coquina Facies

The Coquina facies of the Anastasia Formation crops out at numerous localities in the coastal sections of Palm Beach and Martin Counties. The rock is white to tan on a freshly exposed surface and weathers gray to brown. It consists of shell fragments and quartz sand bound together by calcium carbonate cement. A few heavy mineral grains and coquina pebbles are also present. The sand grains and heavy minerals were probably carried into the area from the Carolinas and Georgia by means of the longshore current. The shell fragments and coquina pebbles originated locally.

Quartz particles in the coquina are the size of fine to coarse sand; they are angular to rounded and the sorting is poor. The shell materia in the coquina takes one of the following forms:

(1) sand-sized shell fragments mixed with quartz grains to produce typical coquina,

(2) shell hash layers composed of fragments averaging up to 12 mm (1 1/2 in) long; few if any quartz grains are present and porosity is high,

(3) thin accumulations of whole or broken shells up to 7.5 cm (3 in) long on the bedding planes; these are interpreted lag deposits left behind by the winnowing action of waves or currents, and

(4) isolated whole or broken shells up to 20 cm (8 in) long. In the southern part of Palm Beach County the shell material found in the coquina is predominantly of sand size. From Palm Beach northward larger shell fragments become more abundant, possibly due to the greater width of the continental shelf offshore. The shell fragments in the coquina are usually well worn and polished; often they are discoidal with rounded edges. Mollusks make up the bulk of this material. Recognizable fragments or whole shells of the following are present: *Arca sp., Busycon contrarium, Chione cancellata, Crassostrea virginica, Crepidula fornicata, Dinocardium robustum, Donax variabilis, Mercenaria mercenaria, and Peoten ziczac.*

The Shellrock Facies

The shellrock facies of the Anastasia Formation is found west of Interstate Highway I-95, and it constitutes a valuable economic resource (Schmidt, et al., 1979). It is not visible at the surface because it is covered by a thick layer of Holocene sand; it is seen only in shellrock pits that are being actively mined. The shellrock is bluish-gray when first excavated from below the water table and creamy white after it has been allowed to dry. It is composed of large unbroken shells, primarily Mollusks, in a matrix of fine to medium quartz sand. The sand grains are often highly angular. Unlike the coquina facies of the Anastasia Formation, in which shells almost always occur as broken fragments, shell material in the shellrock facies is generally whole.

The fossils found in the shellrock facies are notable for their variety, their large size and their excellent state of preservation. Hard parts are unaltered except for loss of color and nacreous luster; upon drying the shells become chalky white. Twenty-five genera of gastropods are present, fifteen genera of pelecypeds, a branching coral, a sand dollar, and several bone fragments. Pelecypod valves are frequently still articulated, suggesting a low-energy depositional environment characterized by little wave or current activity.

The shellrock is not well cemented, which is an advantage in mining operations. Once the rock has dried, it can be easily crushed. A problem encountered in mining, however, is that the shellrock is often overlain by a layer of highly indurated, massive sandstone, referred to as the "cap rock" by pit operators. The cap rock must frequently be blasted in order to get at the shellrock.

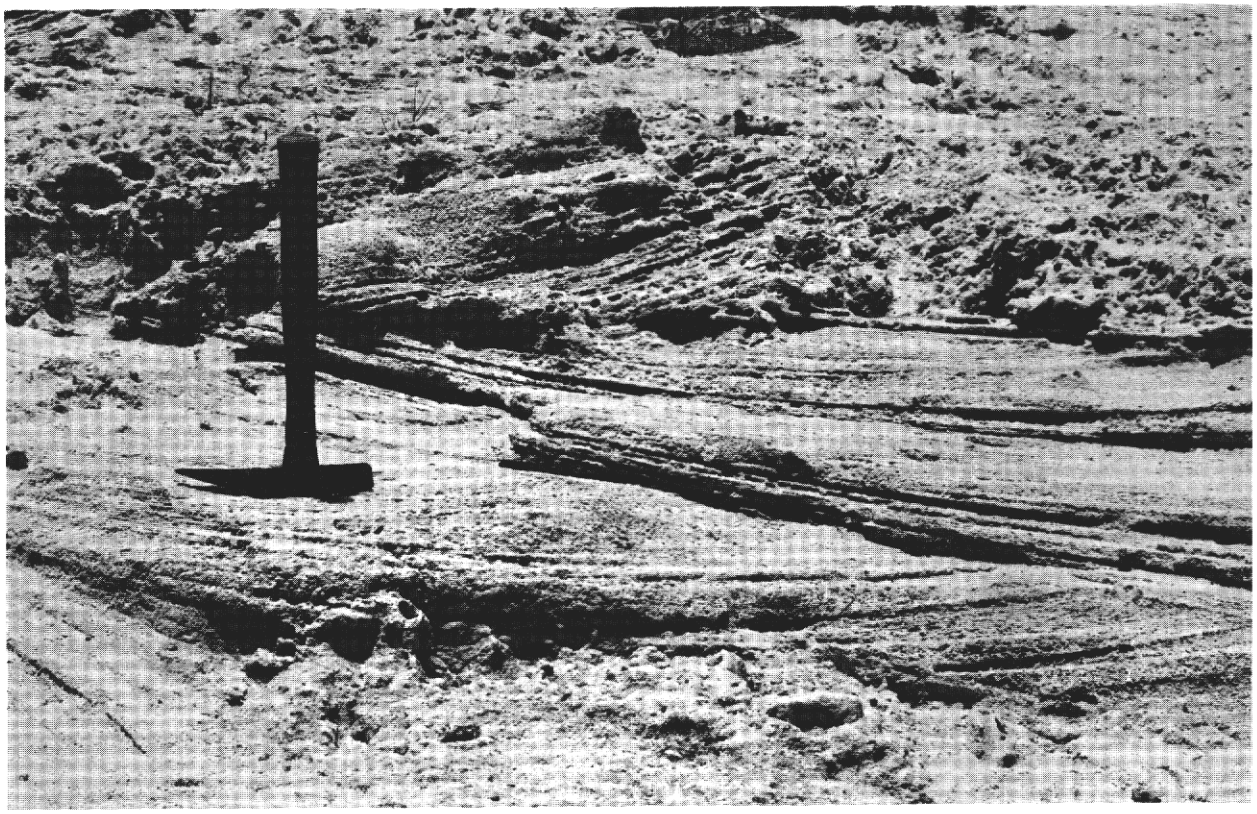

Figure 3. Herringbone cross-bedding in coquina, south of Gulfstream Park.

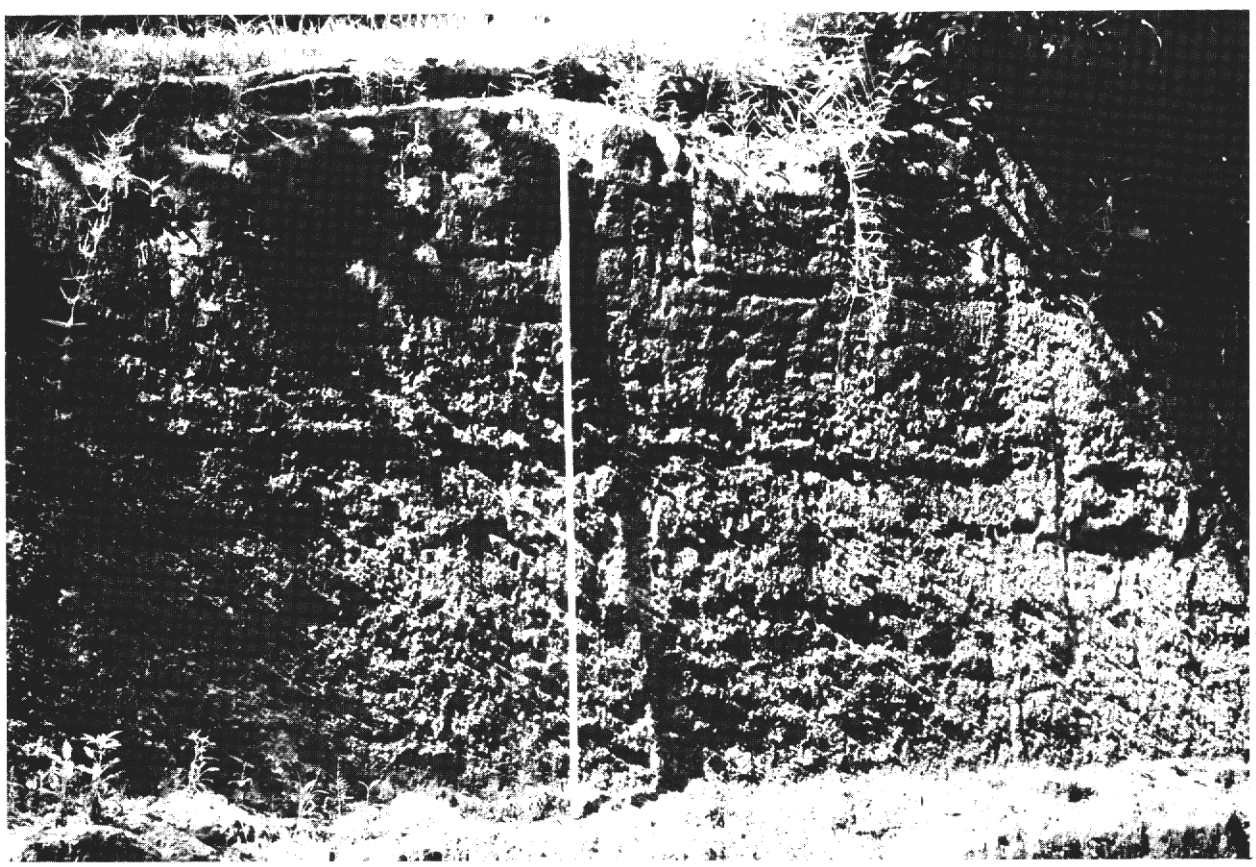

Figure 4. Avalanche cross-bedding in coquina, Palm Beach Road Cut. Stick is 1.8 m (6 ft.) long. Horizontal markings were made during excavation of road cut.

SEDIMENTARY STRUCTURES OF THE ANASTASIA FORMATION

Important sedimentary structures found in the Anastasia Formation in Palm Beach and Martin Counties include bedding, burrows, calcitic crusts, and lithified infillings.

Bedding

The coquina facies may contain planar bedding, in which the individual layers are parallel to the main planes of stratification in the rock, or cross-bedding in which the individual layers are inclined at an oblique angle to the main planes of stratification. If the rock surface is smooth, the bedding may give the rock a noticeably banded appearance. Where the surface of the rock is weathered, the rock may have a ribbed appearance with resistant layers standing out as ridges and the less resistant layers indented as grooves (Fig. 2).

The bedding in the coquina is caused by one or more of the following factors:

(1) differences in grain size between one layer and another,

(2) differences in composition between one layer and another, especially the amount of shell material present,

(3) varying degrees of cementation between one layer and another,

(4) color differences between one layer and another, usually due to the presence of shell material or iron staining, and

(5) shell fragments lying oriented with their longest dimensions parallel to the depositional surface.

At several localities the coquina is noticeably cross- bedded. Two types of cross-bedding are recognized: herringbone cross-bedding and avalanche cross-bedding. Herringbone cross-bedding occurs when the oblique layers are inclined first in one direction and then in the opposite direction, giving the rock a herringbone appearance when viewed in cross-section (Fig. 3). This type of cross-bedding is believed to be produced by shifting current directions, such as tidal currents in the littoral zone. Avalanche cross-bedding results when all the oblique layers dip uniformly in the same direction (Fig. 4). This type of cross- bedding is characteristic of water-laid sediments and the oblique layers dip in the direction that the current was moving. Halley and Evans (1983) describe this type of cross-bedding from the Miami Limestone and believe it was formed by the avalanching of sand grains down the slip faces of advancing sand waves.

Burrows

The coquina facies of the Anastasia Formation contains many tubular structures that were first interpreted as fossilized root networks (Lovejoy, 1983) based on comparisons with similar structures at Mangrove Reef in Miami (Hoffmeister and Multer, 1965). These structures are now believed to represent animal burrows similar to those reported from the Miami Limestone by Halley and Evans (1983). Two distinct types of burrows are recognized in Palm Beach and Martin Counties; Type # 1 and Type # 2 burrows.

Type # 1 burrows are found at the crests of the outcrops and may extend downward as much as 1.8m (6 ft.). The burrows have roughly circular cross-sections up to 2.5 cm (1 in) in diameter. Although vertical burrows predominate, horizontal burrows are also seen. The burrows are usually closely spaced and may be straight, curved or irregular. Their outer surface has a knobby appearance. Downward branching is rare but when it occurs the two branches may reunite again.

Figure 5. Type # 1 burrows on upper surface of ourcrop, showing micritic linings, Singer Island.

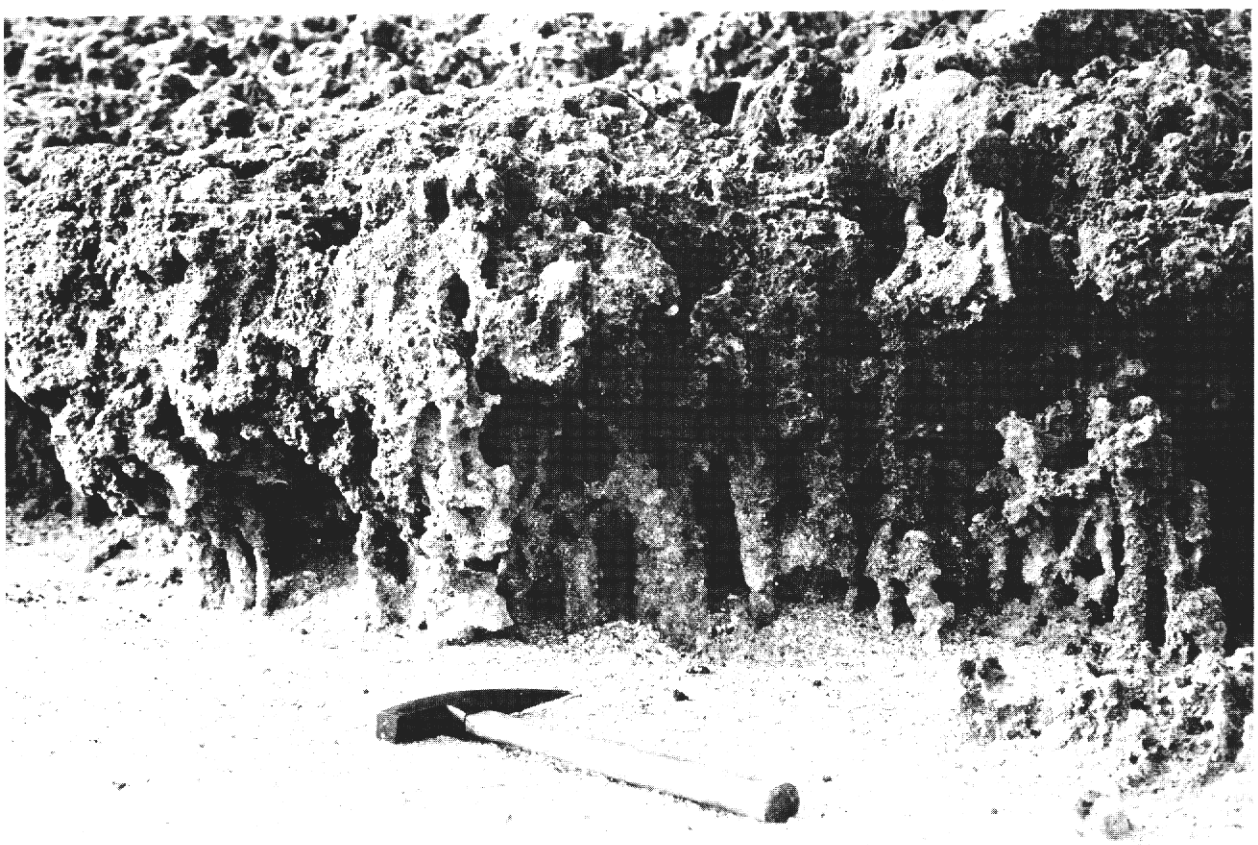

Figure 6. Type # 1 burrows on side of outcrop, Blowing Rocks.

The burrows have fine-grained micritic walls with the interiors hollow or filled by slightly coarser coquina. Because of the hard micritic linings the burrows usually stand out in sharp relief, giving the upper surface of the outcrops a cratered appearance (Fig. 5). The sides of the outcrops resemble interwoven rods (Fig. 6).

Type # 2 burrows are found primarily at the base of the outcrops (Fig. 2). They appear to extend downward from the surface 3 m (10 ft) or more. They are widely spaced, with circular to lenticular cross-sections 5 cm (2 in) or more in diameter. These burrows may be vertical, inclined or horizontal; horizontal burrows are common. The burrows increase and decrease in size irregularly, giving them a nodular appearance. They have micritic linigs and stand out from the rock in relief. Hollow Type # 2 burrows are occasionally encoutered.

Type # 1 and Type # 2 burrows are not considered to be fossilized root networks for the following reasons: (1) they do not taper to a point downward as would be expected of roots, (2) they do not subdivide into smaller tubes downward as would be expected of roots, (3) they have knobby exteriors or lenticular cross- sections which are atypical roots, and (4) they have micritic linings which are atypical of roots. At least two different types of burrowing organisms appear to be involved. One may be Callianassa sp. which has been reported from the Miami Limestone by Halley and Evans (1983). The presence of these burrows is believed to indicate a low-energy environment where sand was not actively moved by waves or currents.

Crusts

Calcium carbonate crusts are present on the surface of the Anastasia Formation. The crusts found on the coquina are relatively thin, averaging 2.5 cm (1 in) thick, and are laminated (Fig. 7). They conform to the underlying surface of the coquina and even follow it down into solution pits and holes (Fig. 8). Individual laminae are on the order of 1 mm (0.04 in) thick and are composed of alternating white and reddish-brown layers. The upper surface of the crust is generally reddish-brown and smooth.

Robbin and Stipp (1979) described similar crusts from the Florida Keys and concluded that they were formed in a subaerial environment by upward accretion beneath a thin layer of humic soild. They attributed the brown color to included organic matter and minute traces of iron. A similar origin is postulated for the crusts on the coquina facies of the Anastasia Formation.

The cap rock overlying the shellrock facies of the Anastasia Formation is also believed to represent a calcium carbonate crust. This cap rock consists of fine- to medium-grained quartz sand cemented with calcium carbonate. The cap rock is 1.3 m (4 ft.) or more thick and has a white to pale yellow color. No fossils or laminations are present. Pit operators state that the cap rock is found only beneath areas covered by pine tree vegetation, suggesting that accretion beneath humic soil is a factor, as in the origin of the crusts on the coquina.

Lithified Infillings

The coquina facies of the Anastasia Formation contains many solution cavities which are readily filled by loose material. In many places these infillings have been partially or completely lithified by calcium carbonate cement, and it is important not to mistake the shell fragments in these lithified infillings for original fossil contents of the rock. In addition to whole or broken shells, pieces of coral and coquina pebbles are also found in these lithified infillings. Often the infillings are more thoroughly cemented than the coquina itself, with the result that they project above the rock surfaces as resistant knobs. Similar knobs have been reported from the Anastasia Formation at Washington Oaks State Park in Flagler County by Meeder, et al (1981).

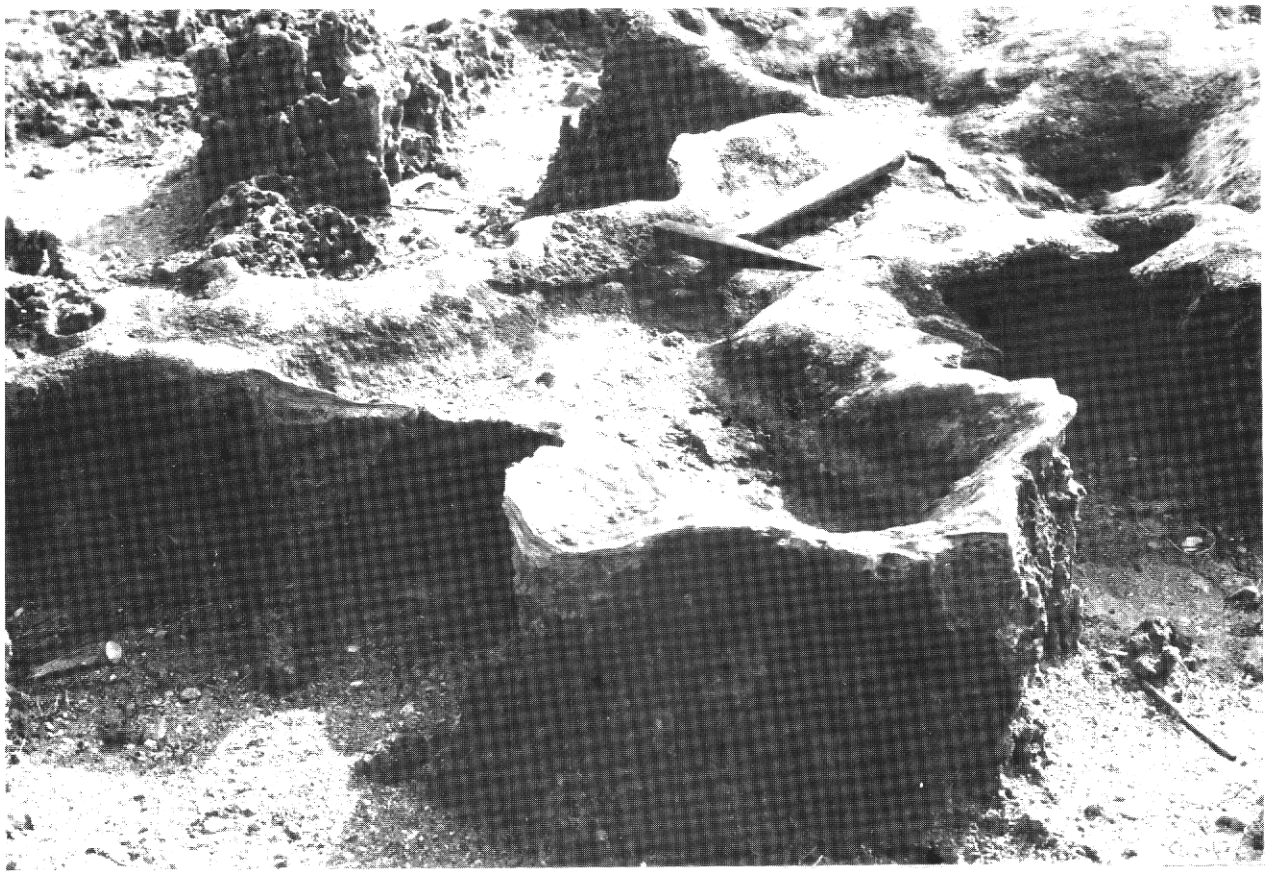

Figure 7. Laminated calcium carbonate crust on surface of burrowed coquina, House of Refuge.

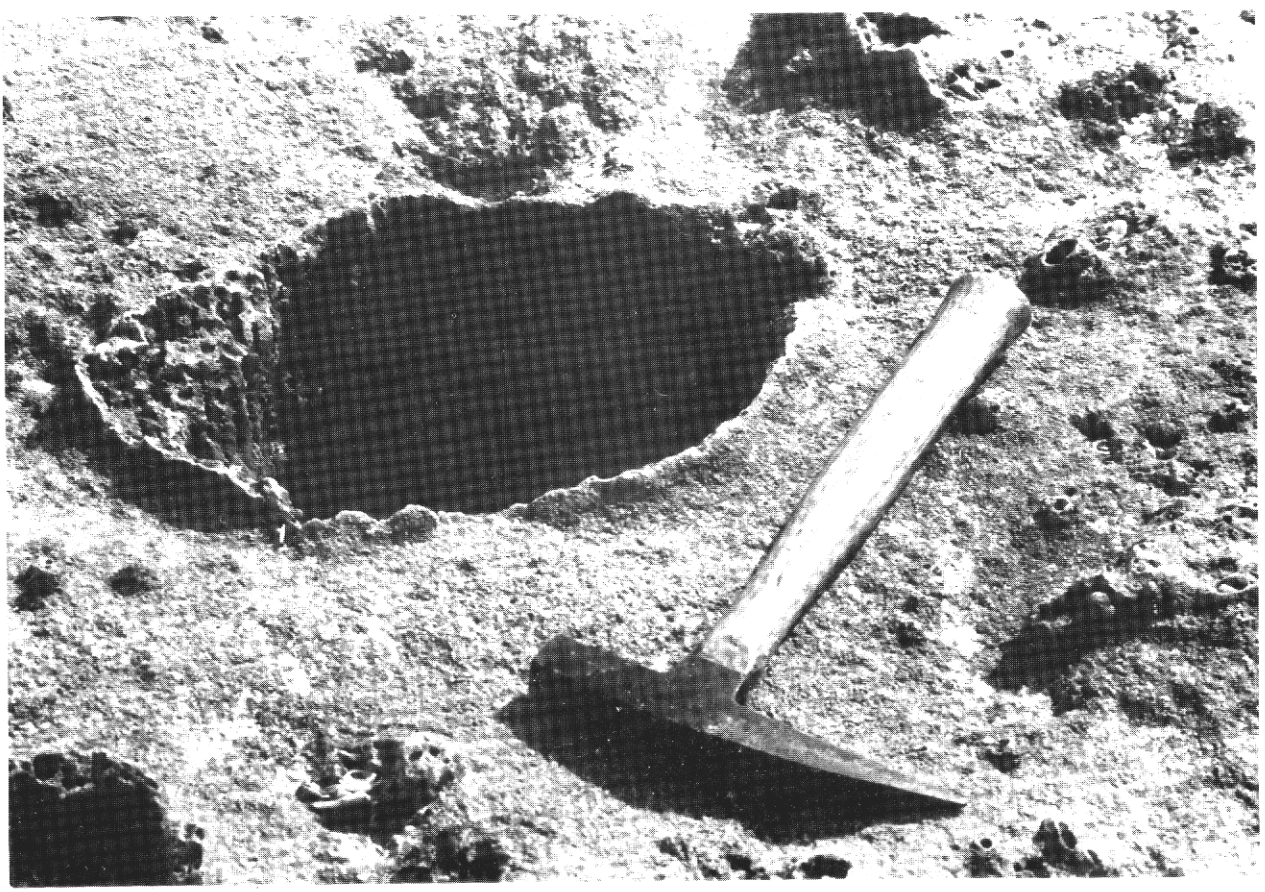

Figure 8. Calcitic crust extending down into solution hole, Singer Island.

MAJOR OUTCROPS OF THE ANASTASIA FORMATION

The Anastasia Formation crops out at many places along the coast in Palm Beach and Martin Counties. The most important outcrops are indicated in Figure 1 and discussed below. Other outcrops of a minor nature are found along the beach, on private property adjacent to Higway A1A, or in the intertidal zone of the Intracoastal Waterway. The most significant waterway outcrops are those on the west side of the Bingham Islands, south of the Southern Boulevard Causeway in West Palm Beach, and around Munyon Island, north of Blue Heron Bridge in Riviera Beach. In both places the rock is a typical coquina. A thickness of about 0.6 m (2 ft.) is exposed and there are traces of Type # 1 burrows and calcitic crusts. It is inferred that these outcrops are parts of former bars.

South Beach, Boca Raton

The outcrops begin at the south end of South Beach Park and extend southward along the beach for 0.5 km (0.3 mi) as ledges and low knobs. A thickness of 2.4 m (8 ft) of bedrock is exposed. The rock is typical coquina with planar beds 12 mm (1/2 in) to 2.5cm (1 in) thick. These beds dip 8^{o} eastward along the cliffed edges of the outcrops and are overlain by herrigbone cross-bedding which is burrowed. The burrows are of the Type # 1 variety. Horizontal burrows are well developed and vertical burrows extend down 0.6 m (2 ft) into the coquina. They all have micritic linings, as previously discussed.

Jap Rock

Jap Rock is located just north of Boca Raton at the south end of Highland Beach. The outcrops run northward from Jap Rock for about 2.7 km (1.7 mi) as a series of ledges and low knobs. These outcrops may be more or less covered with sand depending upon the time of year. The rock is a typical coquina with a maximum thickness of 1.8 m (6 ft) exposed.

The coquina has planar bedding with individual layers 1.5 mm (1/16 in) and thicker. Dips range from horizontal to 8o west, grading into avalanche cross-bedding that dips 30o to 35o west. These dips are highly suggestive of advancing sand waves, and the rounded upper surface of the outcrops may represent the tops of the former sands waves. Herringbone cross-bedding is present on top of the outcrops, and Type # 1 vertical burrows extend at least 0.9 m (3 ft) down into the rock.

Large slabs of coquina are strewn about on the beach and in the surf zone. They have flat tops and bottoms which are roughly parallel to the bedding. Presumably they have been detached from the outcrops by wave erosion along less resistant bedding planes. A number of vertical joints of varying orientation cut the rocks and these may have contributed to giving the slabs their shapes. Redish-brown calcitic crusts up to 7.5 cm (3 in) thick are also present.

Gulfstream Park

Gulfstream Park is located on Highway A1A just north of the town of Gulfstream. The outcrops extend southward from the park for 0.6 km (0.4 mi) and consist of ledges in the surf zone and knobs on both side of a large bulkhead. The rock is typical coquina with a maximum thickness of 2.4 m (8 ft) exposed. The coquina has beds 1.5 mm (1/16 in) and thicker. Avalanche cross-bedding dips 30o west at the base of the cliffs and herringbone cross-bedding is present on the cliff tops. Vertical Type # 1 burrows with micritic linings extend downward 0.9 m (3 ft) or more through the bedding, and horizontal burrows are also well developed. Laminated calcitic crusts up to 2.5 cm (1 in) thick are present and there are a few vertical joints with random orientations. Two other outcrops with herringbone cross-bedding can be seen along Highway A1A just north of Gulfstream Park in low road custs. These road cuts are located between Woolbright Road and

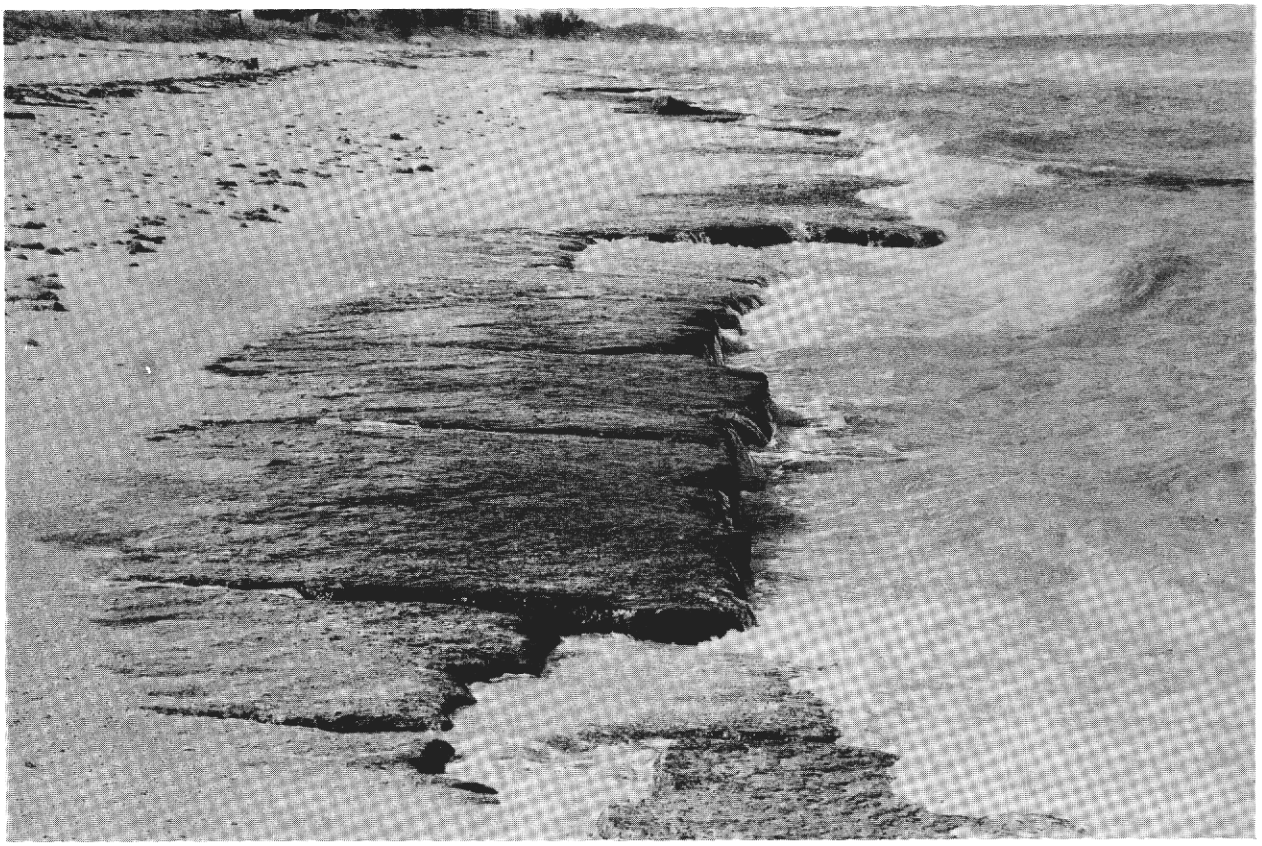

Figure 9. Coquina slabs bounded by bedding planes and east-west joints,south of Phipps Park.

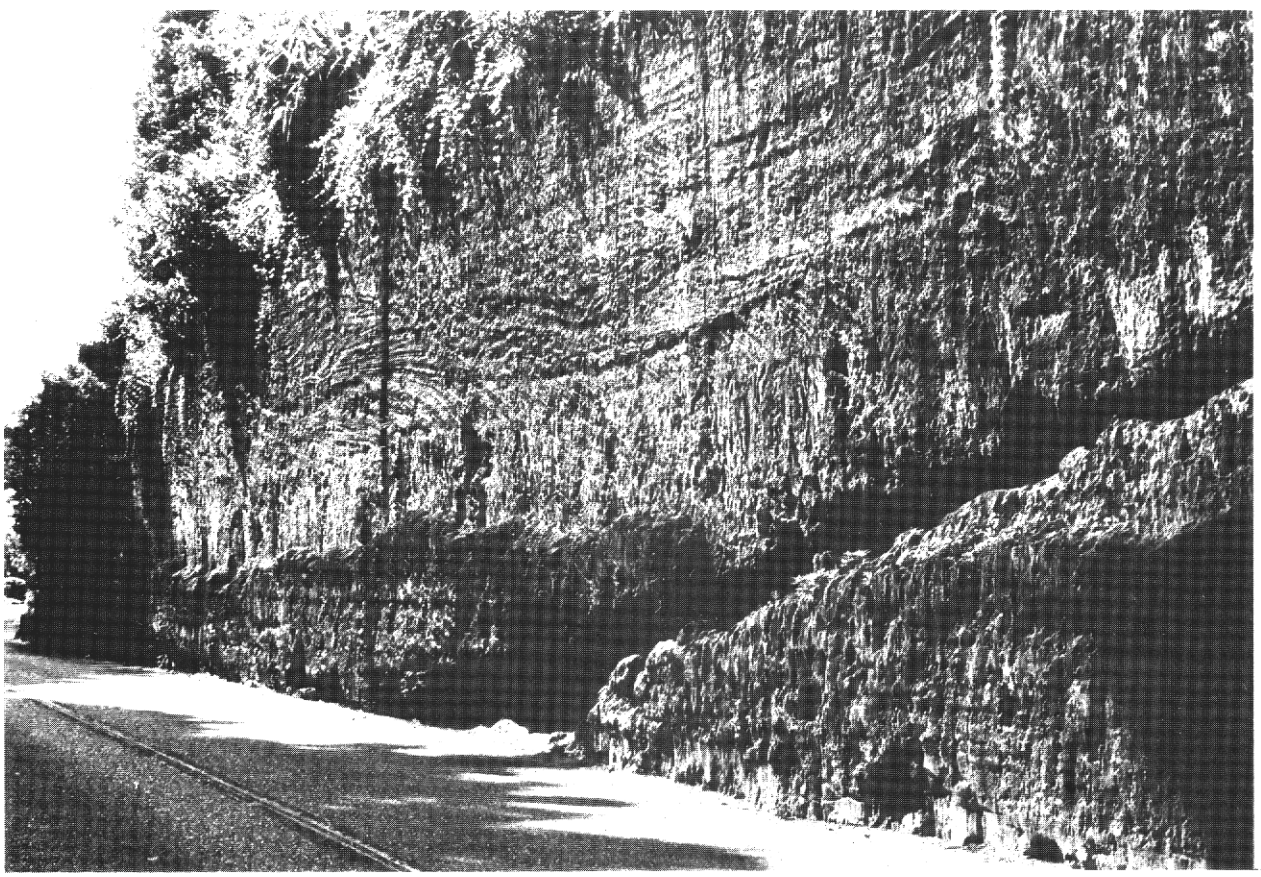

Figure 10. Undulating cross-bedding and disconformity, Palm Beach Road Cut.

Ocean Avenue, on the west side of the highway. At both outcrops the rock is typical coquina. These outcrops may be parts of former bars.

Phipps Park

Phipps Park is located along Highway A1A at the south end of Palm Beach. The outcrops extend southward from the park for 8 km (5 mi) as rocky ledges in the surf zone. These outcrops may be more or less covered with sand depending on the time of year. The rock is typical coquina. Occasional shell fragments up to 2.5 cm (1 in) long are present. A maximum thickness of 0.6 m (2 ft) is exposed. Poorly defined planar bedding dips horizontally or 5o east and there are prominent vertical joints with an east- west orientation. As a result, the waves have eroded the coquina into roughly square slabs resembling pieces of highway pavement (Fig. 9). The local residents are convinced that these slabs are remnants of Highway A1A that were washed into the ocean by a hyrricane years ago.

Palm Beach Road Cut

The outcrop is 180 m (600 ft) long and begins at the west end of Country Club Drive, 0.6 km (0.4 mi) from the beach. Because the road trends east-west, and the topographic high representing the former bar trends north-south, the road cut provides an excellent transverse cross-section through the bar. The outcrop consists of typical coquina at the east and grades into a fine-grained shell hash at the west end. This shell hash is made up of shell fragments averaging 3 mm (1/8 in) in size. Occasional larger shell fragments are present. A maximum thickness of 6 m (20 ft) of coquina is exposed. The outcrop is case hardened: the outer surface of the coquina is well indurated but the interior is quite soft. At the eastern end of the outcrop avalanche cross-bedding dips 31o west. Midway through the road cut, the bedding undulates from horizontal to 31o west. A scour-and-fill structure is also present, truncating the cross-bedding beneath it. Within the scour-and-fill structure avalanche cross-bedding dips 27o west. In addition, a deeply weathered surface cuts across the outcrop, dipping 8o east (Fig. 10). This surface was called an unconformity by Parker, et al (1955) and a disconformity by Perkins (1977). Burrows appear to be present beneath this surface. Type # 1 burrows are poorly developed on the upper surface of the outcrop, and there are a few calcitic crusts. Structures that may be Type # 2 burrows extend vertically downward 3 m (10 ft) or more into the outcrop. Perkins (1977) called these structures root calcifications.

Singer Island

The outcrops begin behind the Hilton Irn as a reef which is favord by snorklers, and continue northward for 0.6 km (0.4 mi) as low cliffs. A maximum thickness of 2.4 m (8 ft) is exposed. The rock is a typical coquina and is burrowed throughout. There is an indication of low-angle herringbone cross-bedding at the crest of the outcrop and avalanche cross-bedding dips 27o west at the north end. Vertical Type # 1 burrows predominate. They have micritic walls and hollow interiors, giving the surface of the rock a cratered appearance. The burrows extend down into the rock at least 1.8 m (6 ft). Diameters of the burrows range up to 4 cm (1 1/2 in) and the micritic linings are as much as 9 mm (3/8 in) thick. Type # 2 burrows appear to be present at the base of the outcrops as well.

Calcitic crust are also well developed. They range up to 10 cm (4 in) or more in thickness and have alternating reddish-brown and white laminations. Lithified infillings also appear. Many of the cavities that contain them are filled with reddish-brown calcitic crusts. The fillings consist of shell fragments, rounded blocks of coquina up to 27 cm (11 in) long, pieces of coral, and/or thick accumulations of laminated white calcitic crust. Some of the infillings are so resistant to erosion that they project above the rock surface as knobs.

Juno Beach

The outcrops extended as ledges and low knobs from Celestial Way to Lost Tree Village. A maximum thickness of 2.1 m (7 ft) is exposed. The rock is typical coquina. Shell hash layers and a few isolated large shells are also present. Horizontal planar bedding is poorly developed in the lower parts of the outcrops, and the rock is frequently iron stained. The outcrops are intensively burrowed. Vertical burrows of the Type # 1 variety predominate, although horizontal burrows are also present. The vertical burrows extend 1.2 m (4 ft) down into the rock and have micritic linings. Nodular burrows of the Type # 2 variety appear to be present at the base of the outcrops as well. Calcitic crusts are well developed, they are 10 cm (4 in) or more in thickness, have white and/or reddish-brown laminations, and bend down into solution holes on the outcrops. Lithified infillings are also present, as well as a number of irregular vertical joints, many of which display a north-south trend.

Carlin Park

Carlin Park is located 1.6 km (1 mi) south of Jupiter inlet. The outcrops begin at the north end of the park and extend northward for 0.5 km (0.3 mi) as a series of low cliffs. A maximum thickness of 1.2 m (4 ft) is exposed. The rock is a typical coquina and includes shell hash layers, shell lag deposits, and isolated large shells. Planar bedding is well developed, with individual layers ranging from 6 mm (1/4 in) to 2.5 cm (1 in) thick. Dips vary from horizontal to 7o seaward. Type # 1 burrows are rare but horizontal burrows of the Type # 2 variety appear at the base of the outcrops. Many of these burrows stand out in sharp relief because of their hardened micritic linings. Solution holes with reddish-brown calcitic linings are also present, as well as iron-stained lithified infillings. Many of these lithified infillings stand above the outcrop surfaces as resistant knobs.

Blowing Rocks

Blowing Rocks Preserve is located along Highway A1A just north of the Martin County line. A short distance to the south is Blowing Rocks Park, also known as "Little Blowing Rocks," where the rocks are similar. In Blowing Rocks Preserve a prominent ocean front cliff extends for 1.6 km (1 mi). It provides an excellent longitudinal cross-section down the length of the former bar. The rock is a typical coquina. Shell hash layers, shell lag deposits, isolated large shells, and shingle-shaped coquina pebbles up to 20 cm (8 in) long are also present. A thickness of 3.6 m (12 ft) of coquina is exposed.

The base of the cliff has planar bedding with individual layers as thin as 1.5mm (1/16 in) thick. Dips vary from 7o west to horizontal to 10o east, suggesting the crest of a former bar. Both horizontal and vertical Type # 1 burrows are well developed along the cliff top. The vertical burrows extend down at least 1.8 m (6 ft) into the rock. Nodular Type # 2 burrows appear at the base of the cliff. There are calcitic crusts with alternating reddish-brown and white laminations. These crusts are up to 7.5 cm (3 in) thick and have smooth reddish-brown surfaces. Lithified infillings are also present, and a few irregular vertical joints trend north-south.

There are additional outcrops along the Intracoastal Waterway at Blowing Rocks Preserve. The rock is a typical coquina with a maximum thickness of 0.6 m (2 ft) exposed. Planar bedding dips 5o east, suggesting a bar parallel with the one exposed along the beach. Type # 1 burrows and calcitic crusts are also present.

House of Refuge

The house of Refuge is 2.1 km (1.3 mi) south of Highway A1A at the south end of Hutchinson Island, near Stuart. Coquina crops out for 3.2 km (2 mi) along the shoreline. Shell hash layers,

shell lag deposits, isolated large shells, and shingle- shaped coquina pebbles are also present. A maximum thickness of 4.8 m (16 ft) is exposed. The lower part of the cliffs has planar bedding with individual layers as thin as 6 mm (1/4 In). Dips vary from 7o west to horizontal to 10o east, suggesting the crest of a former bar. The upper part of the outcrops has Type # 1 horizontal and vertical burrows. Type # 2 burrows can be seen extending down at least 3 m (10 ft) through the upper burrowed zone into the planar bedding at the base of the cliffs. There are laminated, reddish-brown calcitic crusts up to 7.5 cm (3 in) thick, and lithified infillings are also present.

DEPOSITIONAL ENVIRONMENT OF THE ANASTASIA FORMATION

The coquina facies of the Anastasia Formation is believed to have been deposited as a series of offshore bars, based on the following evidence:

(1) The presence of bedding, oriented shell fragments, shell hash layers, shell lag deposits, and large shells all suggest deposition in water by means of waves or currents.

(2) The pattern of the bedding strongly suggests elongate bars with horizontal layers along the crest and strata dipping gently east and west along the flanks. Today offshore bars are present 200-300 m (650-1000 ft) from the shoreline; waves can be seen breaking over them when the surf is high. The crests of these bars are 6-9 m (20-30 ft) wide, and they stand in 0.6-0.9 m (-3 ft) of water at low tide.

(3) Outcrops of coquina in the Intracoastal Waterway suggest additional bars parallel to the bars along the beach. Parallel bars also occur offshore today's waves can be seen breaking and re-forming two or three times as they cross them.

(4) The presence of avalanche cross-bedding suggests that from time to time the bars grew rapidly forward just as sand waves in the Bahamas do today (Halley and Evans, 1983).

(5) The presence of disconformities and scour-and-fill structures suggest that the bars were subject to modification by violent storms just as the offshore bars are today.

The bedded coquina is believed to have formed in high-energy portions of the offshore bar complex, where sand was kept in constant motion by the waves and currets. The burrowed coquina is thought to represent low-energy portions of the offshore bar complex, where wave and current activity was minimal and there was a corresponding reduction in the rate of sedimentation. These areas are believed to have contained large faunas of burrowing organisms. The location of the high-energy and low-energy portions of the offshore bar complex may have been controlled by tidal channels that connected the ocean with the shallow bay behind the bars. These channels may have influenced the amount of sediment the bars received, as well as the rate of deposition or erosion. Furthermore, these channels probably migrated back and forth with time, just as present-day inlets do along the coast of Florida when they are not extabilized by Man.

The shellrock facies of the Anastasia Formation is believed to have been formed in the shallow bay behind the offshore bars. Herelow-energy conditions provided the quiet water necessary for the presence of a large and varied molluscan fauna. The evidence for a shallow bay origin is as follows:

(1) the matris is fine-to medium-grained pure quartz sand and coarse materials such as coquina pebbles are lacking,

(2) the fossil shells have been preserved whole with few shell fragments present,

(3) the fossil shells show no sign of having been worn by waves or currents,

(4) the bivalves are still articulated, and

(5) the fauna is composed of animals living in low-energy environments today.

CONCLUSIONS

Based on its lithology, fossil contents, and sedimentary structures, the Pleistocene Anastasia Formation of Palm Beach and Martin Counties is believed to have been deposited in a shallow-water, near-shore marine environemtn consisting of an offshore bar complex with a protected shallow bay behind it. The bedded and burrowed coquina are believed to have been deposited in high- energy and low-energy portions of the offshore bar complex respectively, and the shellrock is believed to have been deposited in the low-energy environment of the shallow bay behind the offshore bars.

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